ROYAL INSTITUTION OF GREAT BRITAIN.

Friday, May 15, 1857.—The Lord Wensleydale, Vice-President, in the Chair.

"On the present state of Knowledge as to the Structure and Functions of Nerve." By Thomas H. Huxley, F.R.S., Fullerian Professor of Physiology, Royal Institution.

The speaker commenced by directing the attention of the audience to an index, connected with a little apparatus upon the table, and vibrating backwards and forwards with great regularity. The cause of this motion was the heart of a frog (deprived of sensation, though not of life) which had been carefully exposed by opening the pericardium, and into whose apex the point of a needle connected with the index had been thrust. Under these circumstances the heart would go on beating, with perfect regularity and full force, for hours; and as every pulsation caused the index to travel through a certain arc, the effect of any influences brought to bear upon the heart could be made perfectly obvious to every one present.

The frog's heart is a great hollow mass of muscle, consisting of three chambers, a ventricle and two auricles, the latter being separated from one another by a partition or septum. By the successive contraction of these chambers, the blood is propelled in a certain direction; the auricles contracting, force the blood into the ventricle; the ventricle then contracting, drives the blood into the aortic bulb; and it is essential to the full efficiency of the heart as a circulatory organ, that all the muscular fibres of the auricles should contract together, and that all the muscular fibres of the ventricle should contract together; but that the latter should follow the former action after a certain interval.

The contractions of the muscles of the heart thus occur in a definite order, and exhibit a combination towards a certain end. They are rhythmical and purposive; and it becomes a question of extreme interest to ascertain, where lies the regulative power which governs their rhythm.

If we examine into the various structures of which the heart is composed, we find that the bulk of the organ is made up of striped muscular fibres, bound together as it were by connective tissue, and coated internally and externally with epithelium. Now it is certain that the regulative power is not to be found in any of these tissues. The two latter may, for the present purpose, be regarded as unimportant, as they certainly take no share either in producing or guiding the movements of the heart. The muscular tissue, on the other hand, though the seat of the contractility of the organ, requires some influence from without, some stimulus, in order to contract at all, and having once contracted, it remains still until another stimulus excites it. There is, therefore, nothing in its muscular substance which can account for the constantly recurring rhythmical pulsations of the heart.

Experiments have been made, however, which clearly show that the regulative power is seated, not only in the heart itself, but in definite regions of the organ. Remove the heart from the body, and it still goes on beating; the source of the rhythm is therefore to be sought in itself. If the heart be halved by a longitudinal section, each half goes on beating; but if it be divided transversely, between the line of junction of the auricles with the ventricle and the apex of the latter, the detached apex pulsates no longer, while the other segment goes on beating as before. If the section be carried transversely through the auricles, both segments go on beating; and if the heart be cut into three portions by two transverse sections, one above the junction of the auricles and ventricle, and one below it, then the basal and middle segments will go on pulsating, while the apical segment is still. Clearly then, the source of the rhythmical action, the regulative power, is to be sought somewhere about the base of the auricles, and somewhere about the junction of the auricles and ventricles.

Now there is in the frog's heart, besides the three tissues which have been mentioned, a fourth, the nervous tissue. A ganglion is placed at the base of the heart, where the great veins enter the auricles—from this two cords can be traced traversing the auricular septum, and entering two other ganglia placed close to the junction of the auricles with the ventricles. From these ganglia nerves are distributed to the muscular substance. Now we know, from evidence afforded by other striped muscles and nerves, that the contraction of the former is the result of the excitement of the latter; in like manner, we know that the ganglia are centres whence that excitement originates. We are therefore justified, analogically, in seeking for the sources of the contractions of the cardiac muscles, in the cardiac ganglia; and the experiments which have been detailed—by showing that the rhythmical contractions continue in any part of the heart which remains connected with these ganglia, while it ceases in any part cut off from them—prove that they really are the seats of the regulative power.

The speaker then exhibited another very remarkable experiment (first devised by Weber) which leads indirectly to the same conclusion. An electro-magnetic apparatus was so connected with the frog upon the table, that a series of shocks could be transmitted through the pneumogastric nerves. When this was done, it was seen that the index almost instantly stopped, and remained still, so long as the shocks were continued; on breaking contact, the heart remained at rest for a little time, then gave a feeble pulsation or two, and then resumed its full action. This experiment could be repeated at will, with invariably the same results; and it was most important to observe, that during the stoppage of the heart, the index remained at the lowest point of its arc, a circumstance which, taken together with the distended state of the organ, showed that its stoppage was the result, not of tetanic contraction, but of complete relaxation.

Filaments of the pneumogastric nerve can be traced down to the heart, and whenever these fibres are irritated, the rhythmical action ceases. The pneumogastric nerves must act either directly upon the muscles of the heart, or indirectly through the ganglia, into which they can be traced. If the former alternative be adopted, then we must conceive the action of the pneumogastric nerve upon muscle to be the reverse of that of all other nerves—for irritation of every other muscular nerve causes activity and not paralysis of the muscle. Not only is this in the highest degree improbable, but it can be demonstrated to be untrue; for on irritating, mechanically, the surface of the heart brought to a standstill by irritation of the pneumogastrics, it at once contracts. The paralysing influence, therefore, is not exerted on the muscles, and as a consequence, we can only suppose that this "negative innervation," as it might be conveniently termed, is the result of the action of the pneumogastric on the ganglia.

It results from all these experiments, first, that nerve-substance possesses the power of exciting and coordinating muscular actions; and secondly, that one portion of nervous matter is capable of controlling the action of another portion. In the case of the heart it is perfectly clear that consciousness and volition are entirely excluded from any influence upon the action of the nervous matter, which must be regarded as a substance exhibiting certain phænomena, whose laws are as much a branch of physical inquiry as those presented by a magnet.

Now, (still carefully excluding the phænomena of consciousness,) we shall find on careful examination, that all the properties of Nerve are of the same order as those exhibited by the nervous substance of the heart. Every action is a muscular action, whose proximate cause is the activity of a nerve, and as the muscles of the heart are related to its ganglia, so are the muscles of the whole body related to that great ganglionic mass which constitutes the spinal marrow, and its continuation the medulla oblongata. This cranio-spinal nervous centre originates and coordinates the contractions of all the muscles of the body independently of consciousness, and there is every reason to believe that the organ of consciousness stands related to it as the pneumogastric is related to the cardiac ganglia; that volition, whether it originates, or whether it controls action, exerts its influence not directly on the muscles, but indirectly upon the cranio-spinal ganglia. A volition is a conscious conception, a desire; an act is the result of the automatic, unconscious origination and coordination, by the cranio-spinal ganglia, of the nervous influences required to produce certain muscular contractions.

Whatever may be the ultimate cause of our actions then, the proximate cause lies in nerve-substance. The nervous system is a great piece of mechanism placed between the external world and our consciousness; through it objects affect us; through it we affect them; and it therefore becomes a matter of the highest interest to ascertain how far the properties and laws of action of nerve-substance have been ascertained by the physiological philosopher.

Nerve-substance has long been known to consist of two elements, fibres and ganglionic corpuscles. Nerve-fibres are either sensory or motor, and the activity of any one fibre does not influence another. But when nerve-fibres come into relation with ganglionic corpuscles, the excitement of a sensory nerve gives rise to that of a motor nerve, the ganglionic corpuscles acting in some way as the medium of communication. The "grey matter" which occupies the middle of the spinal marrow has long been known to be the locality in which the posterior roots, or sensory fibres, of the nerves of the body, and the anterior roots, or motor fibres, come into relation with ganglionic corpuscles; and as the channel by which, in what are called reflex actions, the activity of the sensory nerves is converted into excitement of corresponding motor nerves. The precise *modus operandi* of the grey matter has been much disputed, but the recent researches of Wagner, Bidder, Kupfer, and Owsjannikow, throw a great light upon, and vastly simplify the whole problem. It would appear that all nerve-fibres are processes of ganglionic corpuscles; that, in the spinal cord, the great mass of the grey matter is nothing but connective tissue, the true ganglionic corpuscles being comparatively few, and situated in the anterior horns of the grey substance; finally, it would seem that no ganglionic corpuscle has more than five processes: one, which becomes a sensory fibre and enters the posterior roots of the nerves; one, a motor fibre which enters the anterior roots; one, which passes upward to the brain; one, which crosses over to a ganglionic corpuscle in the other half of the cord; and perhaps one establishing a connexion with a ganglionic corpuscle on the same side.

It is impossible to overrate the value of these discoveries; for if they are truths, the problem of nervous action is limited to these inquiries: (*a*) What are the properties of ganglionic corpuscles? (*b*) What are the properties of their two, or three, commissural processes? For we are already pretty well acquainted with the properties of the sensory and motor processes.

A short account was next given of the physical and physiological phænomena exhibited by active and inactive nerve; and the phænomena exhibited by active nerve were shown to be so peculiar as to justify the application of the title of "nerve-force" to this form of material energy.

It was next pointed out that this force must be regarded as of the same order with other physical forces. The beautiful methods by which Helmholtz has determined the velocity (not more than about 80 feet in a second in the frog) with which the nervous force is propagated were explained. It was shown that nerve-force is not electricity, but two important facts were cited to prove that the nerve-force is a correlate of electricity, in the same sense as heat and magnetism are said to be correlates of that force. These facts were, first, the "negative deflection" of Du Bois Raymond, which demonstrates that the activity of nerve affects the electrical relations of its particles; and secondly, the remarkable experiments of Eckhard (some of which the speaker had exhibited in his Fullerian course), which proved that the transmission of a constant current along a portion of a motor nerve so alters the molecular state of that nerve as to render it incapable of exciting contraction when irritated.

These facts, even without those equally important though less thoroughly understood experiments of Ludwig and Bernard, which appear to indicate a direct relation between nerve-force and chemical change, seem sufficient to prove that nerve-force must henceforward take its place among the other physical forces.

This then is the present state of our knowledge of the structure and functions of nerve. We have reason to believe in the existence of a nervous force, which is as much the property of nerve as magnetism is of certain ores of iron; the velocity of that force is measured; its laws are, to a certain extent, elucidated; the structure of the apparatus through which it works promises soon to be unravelled; the directions for future inquiry are limited and marked out; thus the solution of all problems connected with it is only a question of time.

Science may be congratulated on these results. Time was, when the attempt to reduce vital phænomena to law and order was regarded as little less than blasphemous: but the mechanician has proved that the living body obeys the mechanical laws of ordinary matter; the chemist has demonstrated that the component atoms of living beings are governed by affinities, of one nature with those which obtain in the rest of the universe; and now, the physiologist, aided by the physicist, has attacked the problem of nervous action—the most especially vital of all vital phænomena—with what result has been seen. And thus from the region of disorderly mystery, which is the domain of ignorance, another vast province has been added to science, the realm of orderly mystery.

MISCELLANEOUS.

On the Saliva of Dolium galea. By Professor Troschel.

Statements have recently been made tending to prove that the boring Mollusca penetrate stones by a purely mechanical action. The following observations of Professor Troschel seem to show that in some cases the perforating action of Mollusca may be due to a chemical cause.

In the 'Voyage of the Astrolabe,' Quoy and Gaimard state that the *Dolium galea*, a Ctenobranchous mollusk nearly allied to the *Buccini*, possesses salivary glands of extraordinary development. They are composed of two lobes, of which the anterior alone is glandular; the posterior forming a sort of pouch which attains the size of a pigeon's egg, and contains an aqueous liquid mixed with bubbles of air. The efferent canal of the gland passes through the nervous ring which surrounds the œsophagus and opens into the buccal cavity in front of the tongue.